

# Trimethylsilylnitrate: a useful reagent for direct synthesis of 2-deoxy-*O*-glycosides from glycols<sup>§</sup>

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This paper is respectfully dedicated to Prof. P.T. Narasimhan  
on the occasion of his 75<sup>th</sup> birthday

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**Abstract:** Trimethylsilylnitrate acts as a useful reagent for the addition of alcohols to glycols forming 2-deoxy-*O*-glycosides in good to excellent yields.

**Keywords:** 2-Deoxy-*O*-glycosides, trimethylsilylnitrate, glycols, ClSiMe<sub>3</sub>, AgNO<sub>3</sub>

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## Introduction

2-Deoxy-*O*-glycosides are integral parts of many prominent biologically active natural products<sup>2</sup> such as aureolic acids,<sup>3</sup> cardiac glycosides<sup>4</sup> and antitumor agents such as calicheamycin.<sup>5</sup> In view of this, many synthetic methods have been developed for the stereoselective synthesis of  $\alpha$  or  $\beta$ -2-deoxy-*O*-glycosides. Although, synthesis of 2-deoxy-*O*-glycosides from 2-deoxysugars bearing a leaving group at the anomeric centre is well known, control of the stereochemistry of the *O*-glycosidic bond is somewhat difficult because of the lack of a stereodirecting substituent at C-2. The leaving groups at the anomeric centre include halides,<sup>6a,b</sup> thioglycosides,<sup>6c</sup> n-pentenyl glycosides,<sup>6d</sup> trichloroacetimidates,<sup>6e</sup> sulfoxides,<sup>6f</sup> phosphites,<sup>6g</sup> and phosphoramidites.<sup>6h</sup> These methods, however, need prior preparation of 2-deoxysugars with a desired leaving group at the anomeric centre. Additionally, iodoglycosylation of glycols using iodonium dicollidine perchlorate (IDCP)<sup>7a,b</sup> or ceric ammonium nitrate (CAN)-NaI<sup>7c,d</sup> are other methods reported in literature but they require reductive de-iodination in the next step to obtain 2-deoxy-*O*-glycosides. Apart from this, direct addition of alcohols to glycols catalyzed by a protic acid (MeOH·HCl,<sup>8a</sup> cation-exchange resin AG 50 WX<sub>2</sub>,<sup>8b</sup> Ph<sub>3</sub>P·HBr<sup>8c</sup>) or a Lewis acid (BBR<sub>3</sub> or BCl<sub>3</sub><sup>9a</sup> and CeCl<sub>3</sub>·7H<sub>2</sub>O-NaI<sup>9b</sup>) has also been reported for this purpose. One of the problems, however, in these direct glycosylations is the possibility of the Ferrier reaction and hence not all

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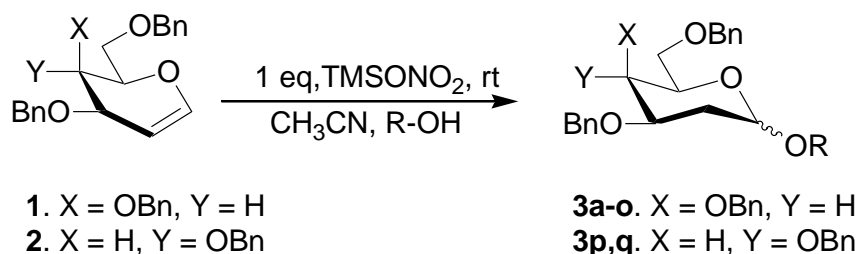
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the protic or Lewis acids are suitable for this purpose. Nevertheless this one pot procedure is useful and hence more recently a polymer-bound Lewis acid<sup>10</sup> has also been employed for the synthesis of 2-deoxy-*O*-glycosides.

## Results and Discussion

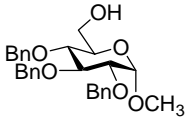
Recently we have reported a CAN catalyzed transformation of glycols to 2-deoxy-*O*-glycosides under mild conditions.<sup>11</sup> As part of our ongoing programme<sup>11,12</sup> to develop newer methods in functionalizing glycols towards obtaining useful carbohydrate intermediates, we have now found that trimethylsilylnitrate (TMSONO<sub>2</sub>), readily made from ClSiMe<sub>3</sub> and AgNO<sub>3</sub>, works as a useful reagent for the synthesis of 2-deoxy-*O*- glycosides. TMSONO<sub>2</sub> has been used<sup>13</sup> in conjunction with BF<sub>3</sub>·Et<sub>2</sub>O as a source of NO<sub>2</sub><sup>+</sup> for nitration of aromatics.



### Scheme 1

We have reported<sup>14</sup> its use along with CrO<sub>3</sub> to convert olefins into  $\alpha$ -nitroketones and in converting cyclic ethers into lactones. More recently, we have found<sup>1</sup> that TMSONO<sub>2</sub> along with Me<sub>3</sub>SiN<sub>3</sub> converts glycols into the corresponding 2-deoxy-1-glycosyl azides which, in turn, can be converted into 2-deoxy- $\beta$ -1-*N*-glycopeptides. In an effort to explore the potential of TMSONO<sub>2</sub>, we report in this paper that TMSONO<sub>2</sub> permits addition of alcohols to glycols forming 2-deoxy-*O*-glycosides in good to excellent yields at room temperature in 2-5 h. A wide variety of alcohols were added on to glycols in the presence of 1 eq. of TMSONO<sub>2</sub>. Initial experiments were performed using catalytic amount of TMSONO<sub>2</sub>, however, the glycols were found to be largely unreacted. Our results are summarized in Table-1. In all the cases,  $\alpha$ -isomer was found to be the major product and in some cases, with a galactal derivative **1** (Scheme 1), it was the exclusive product(entries 1, 2, 11). A disaccharide (entry 14) was also made using this method with galactal **1**, although the yield was moderate. When we used compound **2** (a glucal derivative) under the same reaction conditions, we observed formation of a trace amount of the Ferrier product along with 2-deoxy-*O*-glycosides (entries 16, 17).

**Table 1**

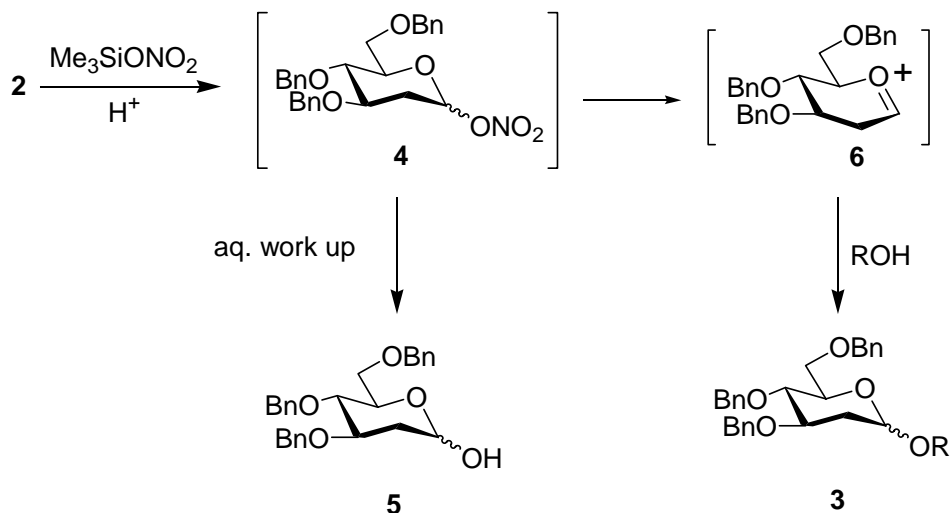
Entry	Glycal	Acceptor	Product <b>3</b>	Yield %	Time (h)	$\alpha$ : $\beta$
1	<b>1</b>	Methanol	<b>a</b> <sup>11</sup>	85	2	$\alpha$ only
2	<b>1</b>	t-Butanol	<b>b</b> <sup>11</sup>	52	5	$\alpha$ only
3	<b>1</b>	Isopropyl Alcohol	<b>c</b> <sup>11</sup>	83	3	90:10
4	<b>1</b>	Propargyl Alcohol	<b>d</b>	95	3	91:9
5	<b>1</b>	Cinnamyl Alcohol	<b>e</b>	89	3	90:10
6	<b>1</b>	Benzyl alcohol	<b>f</b> <sup>11</sup>	85	3	80:20
7	<b>1</b>	Homo propargyl Alcohol	<b>g</b>	90	3	90:10
8	<b>1</b>	3-Bromo-1-propanol	<b>h</b>	92	3	91:9
9	<b>1</b>	Tetrahydrofurfuryl alcohol	<b>i</b>	84	3	90:10
10	<b>1</b>	Cyclohexanol	<b>j</b> <sup>11</sup>	80	4	90:10
11	<b>1</b>	Allyl alcohol	<b>k</b> <sup>11</sup>	81	3	$\alpha$ only
12	<b>1</b>	Cholesterol	<b>l</b> <sup>11</sup>	68	4.5	81:19
13	<b>1</b>	1-Octanol	<b>m</b>	88	3.5	96:4
14	<b>1</b>		<b>n</b> <sup>6h,11</sup>	38	4	92:8
15	<b>1</b>	3-Methyl-but-3-en-1-ol	<b>o</b>	92	3	80:20
16	<b>2</b>	Methanol	<b>p</b> <sup>6i,11</sup>	80	2	(70:30) <sup>a</sup> ,55:45 <sup>b</sup> ,90:10 <sup>c</sup>
17	<b>2</b>	t-Butanol	<b>q</b> <sup>6i,11</sup>	50	4.5	(71:29) <sup>a</sup> ,74:26 <sup>b</sup> ,65:35 <sup>c</sup>

<sup>a</sup> Ratio of 2-deoxy-*O*-glycoside and the Ferrier product. <sup>b</sup>  $\alpha$ : $\beta$  ratio of 2-deoxy-*O*-glycoside.

<sup>c</sup>  $\alpha$ : $\beta$  ratio of the Ferrier product.

With regards to the mechanism of this reaction, we suggest that 2-deoxy-*O*-glycosides are formed via the corresponding nitrate esters **4** (Scheme 2) by the nucleophilic displacement by alcohols under acidic reaction conditions.<sup>15</sup> Evidence to this effect was gathered from the following observations. Exposure of a solution of 3,4,6-tri-*O*-benzyl-D-glucal **2** in acetonitrile to

$\text{Me}_3\text{SiONO}_2$  (1:1 molar equiv) only, followed by analysis of the reaction mixture by thin-layer chromatography showed a polar spot compared to the starting material. Evaporation of solvent under vacuum gave a product which showed in its IR spectrum a strong peak at  $1680\text{ cm}^{-1}$ , whereas its  $^1\text{H}$  NMR spectrum showed peaks of no specific splitting patterns NMR spectrum. Mass spectral analysis using electrospray technique (+ ion) suggested the presence of 1-hydroxy sugar derivative **5**, however, the  $-ve$  ion detection indicated the presence of a peak at  $m/z$  479 corresponding to the nitrate ester **4**.



**Scheme 2**

Further, if the reaction was worked up before the addition of alcohols then the only product that could be isolated was 2-deoxy-3,4,6-tri-*O*-benzyl-D-glucose **5**. It is, therefore, likely that the product of the reaction between a glycal and  $\text{TMSONO}_2$  is a nitrate ester of type **4** which is relatively unstable and gets hydrolyzed to compound **5**. This is not unexpected, since it is known<sup>16</sup> that anomeric nitrates are susceptible towards hydrolysis on column chromatography. Thus, it is fair to assume that the nitrate esters **4** are formed as intermediates in these reactions and then they are subsequently converted to the corresponding 2-deoxy-*O*-glycosides **3** by treatment with glycosyl acceptors viz. the alcohols. Further, we presume that the nitrate esters **4** are first converted to the corresponding oxocarbenium **6**, under the slightly acidic experimental conditions, before reacting with the glycosyl acceptors. This is in view of the fact that the *O*-glycosides formed are predominantly  $\alpha$  in nature, resulting from the dominant anomeric effect.

In conclusion, we have found that  $\text{TMSONO}_2$  is a new reagent for the synthesis of 2-deoxy-*O*-glycosides in a high stereoselective manner from glycals, and we hope that this methodology will be useful in organic synthesis.

## Experimental Section

**General Procedures.** To a stirred solution of a glycol (0.240 mmol) in CH<sub>3</sub>CN (2 mL) at room temperature, were added an alcohol (0.268 mmol) and trimethylsilylnitrate<sup>13</sup> (0.240 mmol). The reaction mixture was stirred for the time indicated in Table-1. After completion of reaction it was extracted with ethyl acetate (2 x 10 mL) and the usual work-up gave a crude product which was purified by column chromatography to give a pure product which was characterized by spectroscopic and analytical means.

**Selected data: propargyl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3d).** Yield: 95%, liquid.  $[\alpha]_D^{25} = +59.5$  (*c* 2.15, CH<sub>2</sub>Cl<sub>2</sub>). IR (CH<sub>2</sub>Cl<sub>2</sub>)  $\nu_{\max}$ : 3300, 2119, 1162, 1065 cm<sup>-1</sup>; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  2.0-2.05 (dd, *J* = 13.0, 4.4 Hz, 1H, H-2), 2.22-2.29 (dt, *J* = 12.6, 3.8 Hz, 1H, H-2'), 2.36 (t, *J* = 2.4 Hz, 1H, -C $\equiv$ C-H), 3.53-3.58 (m, 2H, H-6, H-6'), 3.87-3.93 (m, 3H, H-3, H-4, H-5), 4.16 (t, *J* = 2.4 Hz, 2H, -OCH<sub>2</sub>-C $\equiv$ C), 4.40-4.49 (q, *J* = 11.7 Hz, 2H, -OCH<sub>2</sub>Ph), 4.59 (br. s, 2H, -OCH<sub>2</sub>Ph), 4.63 (d, *J* = 11.7 Hz, 1H, -OCH<sub>2</sub>Ph), 4.93 (d, *J* = 11.7 Hz, 1H, -OCH<sub>2</sub>Ph), 5.14 (br. d, *J* = 3.1 Hz, 1H, H-1), 7.23-7.35 (m, 15H, aromatic). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):  $\delta$  30.7, 54.0, 69.2, 70.2, 70.3, 72.7, 73.3, 74.2, 74.4, 79.3, 96.5, 127.1-138.7 (m, aromatic). MSES<sup>+</sup>: 490 [M + NH<sub>4</sub>]<sup>+</sup>. Anal. Calcd for C<sub>30</sub>H<sub>32</sub>O<sub>5</sub> (472.25): C, 76.25; H, 6.83. Found: C, 76.31; H, 6.88. Characteristic signals for *b*-anomer: <sup>13</sup>C NMR:  $\delta$  32.4, 54.9, 69.0, 70.9, 71.4, 79.1, 97.6, 137.8, 138.1, 138.6.

**Cinnamyl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3e).** Yield: 89%, liquid.  $[\alpha]_D^{25} = +16.0$  (*c* 2.5, CH<sub>2</sub>Cl<sub>2</sub>). IR (CH<sub>2</sub>Cl<sub>2</sub>)  $\nu_{\max}$ : 1495, 1097, 1060 cm<sup>-1</sup>; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  2.02-2.06 (br. dd, *J* = 12.6, 3.4 Hz, 1H, H-2), 2.22-2.29 (dt, *J* = 12.4, 3.68 Hz, 1H, H-2'), 3.54-3.65 (m, 2H, H-6, H-6'), 3.93-3.98 (m, 3H, H-3, H-4, H-5), 4.09-4.14 (dd, *J* = 12.8, 6.7 Hz, 1H, -OCH-CH=CH-Ph), 4.26-4.30 (dd, *J* = 12.8, 5.7 Hz, 1H, -OCH'-CH=CH-Ph), 4.40-4.52 (q, *J* = 11.7 Hz, 2H, -OCH<sub>2</sub>Ph), 4.60 (br. s, 2H, -OCH<sub>2</sub>Ph), 4.62 (d, *J* = 11.5 Hz, 1H, -OCH<sub>2</sub>Ph), 4.93 (d, *J* = 11.5 Hz, 1H, -OCH<sub>2</sub>Ph), 5.10 (br. d, *J* = 3.1 Hz, 1H, H-1), 6.24-6.31 (m, 1H, -OCH<sub>2</sub>-CH=CHPh), 6.57 (br. d, *J* = 15.8 Hz, 1H, -OCH<sub>2</sub>-CH=CHPh), 7.21-7.37 (m, 20H, aromatic). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):  $\delta$  31.1, 67.6, 69.6, 69.9, 70.4, 72.9, 73.4, 74.2, 74.7, 97.1, 125.5, 126.4-128.5 (m, aromatic), 132.6, 136.6, 138.0, 138.4, 138.8. MSES<sup>+</sup>: 568.2 [M + NH<sub>4</sub>]<sup>+</sup>. Anal. Calcd for C<sub>36</sub>H<sub>38</sub>O<sub>5</sub> (550.68): C, 78.52; H, 6.96. Found: C, 78.58; H, 6.93. Characteristic signals for *b*-anomer: <sup>1</sup>H NMR:  $\delta$  4.58-4.60 (dd, *J* = 10.0, 3.8 Hz, 1H, H-1). <sup>13</sup>C NMR:  $\delta$  32.7, 99.0.

**Homo propargyl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3g).** Yield: 90%, liquid.  $[\alpha]_D^{25} = +40.0$  (*c* 1.3, CH<sub>2</sub>Cl<sub>2</sub>). IR (CH<sub>2</sub>Cl<sub>2</sub>)  $\nu_{\max}$ : 3293, 2118, 1162, 1096 cm<sup>-1</sup>; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  1.94 (t, *J* = 2.6 Hz, 1H, -C $\equiv$ C-H), 1.99-2.03 (m, 1H, H-2), 2.19-2.26 (dt, *J* = 12.6, 3.6 Hz, 1H, H-2'), 2.42-2.47 (dt, *J* = 7.0, 2.6 Hz, 2H, -OCH<sub>2</sub>-CH<sub>2</sub>-), 3.53-3.63 (m, 3H, H-6, H-6' and -OCH-CH<sub>2</sub>-), 3.69-3.75 (m, 1H, -OCH'-CH<sub>2</sub>-), 3.89-3.96 (m, 3H, H-3, H-4, and H-5), 4.40-4.51 (q, *J* = 11.9 Hz, 2H, -OCH<sub>2</sub>Ph), 4.59 (br. s, 2H, -OCH<sub>2</sub>Ph), 4.62 (d, *J* = 11.7 Hz, 1H, -OCH<sub>2</sub>Ph), 4.93 (d, *J* = 11.7 Hz, 1H, -OCH<sub>2</sub>Ph), 5.01 (br. d, *J* = 2.9 Hz, 1H, H-1), 7.22-7.34

(m, 15H, aromatic).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  19.7, 31.0, 65.4, 69.2, 69.4, 69.9, 70.4, 72.8, 73.4, 74.2, 74.7, 81.3, 97.9, 127.2-128.3 (m, aromatic), 138.1, 138.4, 138.8.  $\text{MSES}^+$ : 504  $[\text{M} + \text{NH}_4]^+$ . Anal. Calcd for  $\text{C}_{31}\text{H}_{34}\text{O}_5$  (486.59): C, 76.52; H, 7.04. Found: C, 76.55; H, 7.10. Characteristic signals for *b*-anomer:  $^1\text{H}$  NMR:  $\delta$  2.06-2.10 (m, 2H, H-2, H-2'), 4.56-4.59 (dd,  $J = 10.0, 2.2$  Hz, 1H, H-1), 4.91 (d,  $J = 11.7$  Hz, 1H,  $-\text{OCH}_2\text{Ph}$ ).  $^{13}\text{C}$  NMR:  $\delta$  20.0, 32.6, 66.9, 70.1, 71.5, 73.4, 74.0, 100.3, 138.0, 138.3, 138.7.

**3-Bromo-*n*-propyl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3h).** Yield: 92%, liquid.  $[\alpha]_D^{25} = +24.4$  ( $c$  2.05,  $\text{CH}_2\text{Cl}_2$ ). IR ( $\text{CH}_2\text{Cl}_2$ )  $\nu_{\text{max}}$ : 1162, 1096  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  1.95-1.99 (dd,  $J = 12.9, 4.1$  Hz, 1H, H-2), 2.03-2.14 (m, 2H,  $\text{H}_a$ -2), 2.25-2.26 (dt,  $J = 12.7, 3.9$  Hz, 1H, H-2'), 3.43-3.62 (m, 6H, H-5, H-6, H-6',  $\text{H}_a$ -3 and  $\text{H}_a$ -1), 3.73-3.78 (m, 1H,  $\text{H}_a$ -1'), 3.87-3.92 (m, 2H, H-3, H-4), 4.41-4.94 (m, 6H, 3 x  $-\text{OCH}_2\text{Ph}$ ), 4.96 (br. d,  $J = 3.1$  Hz, 1H, H-1), 7.23-7.36 (m, 15H, aromatic).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  30.4, 31.1, 32.5, 64.7, 69.4, 69.9, 70.3, 72.8, 73.4, 74.2, 74.6, 97.9, 126.9-128.4 (m, aromatic), 138.0, 138.4, 138.8.  $\text{MSES}^+$ : 574  $[\text{M} + \text{NH}_4]^+$ . Anal. Calcd for  $\text{C}_{30}\text{H}_{35}\text{BrO}_5$  (555.40): C, 64.86; H, 6.35. Found: C, 64.90; H, 6.41. Characteristic signals for *b*-anomer:  $^{13}\text{C}$  NMR:  $\delta$  30.6, 32.6, 32.7, 66.6, 69.2, 69.6, 70.3, 71.0, 71.5, 73.5, 74.1.

**Tetrahydrofurfuryl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3i).** Yield: 84%, liquid.  $[\alpha]_D^{25} = +31.3$  ( $c$  1.15,  $\text{CH}_2\text{Cl}_2$ ). IR ( $\text{CH}_2\text{Cl}_2$ )  $\nu_{\text{max}}$ : 1202, 1104  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  1.50-1.57 (m, 4H,  $\text{H}_a$ -3,  $\text{H}_a$ -4), 1.96-2.0 (br. dd,  $J = 12.4, 4.6$  Hz, 1H, H-2), 2.18-2.25 (dt,  $J = 13.0, 3.8$  Hz, 1H, H-2'), 3.32-3.66 (m, 6H,  $\text{H}_a$ -1,  $\text{H}_a$ -5, H-6 and H-6'), 3.81-3.95 (m, 4H, H-3, H-4, H-5 and  $\text{H}_a$ -2), 4.42 and 4.50 (2d,  $J = 11.9$  Hz, 2H,  $-\text{OCH}_2\text{Ph}$ ), 4.59 (br. s, 2H,  $-\text{OCH}_2\text{Ph}$ ), 4.61 (d,  $J = 11.5$  Hz, 1H,  $-\text{OCH}_2\text{Ph}$ ), 4.93 (d,  $J = 11.5$  Hz, 1H,  $-\text{OCH}_2\text{Ph}$ ), 4.95 (br. d,  $J = 3.0$  Hz, 1H, H-1), 7.23-7.34 (m, 15H, aromatic).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  29.3, 29.4, 31.8, 67.4, 69.3, 69.5, 69.7, 70.4, 72.9, 73.4, 74.0, 74.2, 74.9, 97.6, 127.2-138.8 (m, aromatic).  $\text{MSES}^+$ : 536  $[\text{M} + \text{NH}_4]^+$ . Anal. Calcd for  $\text{C}_{32}\text{H}_{38}\text{O}_6$  (518.64): C, 74.11; H, 7.39. Found: C, 74.17; H, 7.45. Characteristic signals for *b*-anomer:  $^1\text{H}$  NMR:  $\delta$  2.03-2.10 (m, 2H, H-2, H-2'), 4.57-4.59 (dd,  $J = 9.7, 2.0$  Hz, 1H, H-1), 4.91 (d,  $J = 11.5$  Hz, 1H,  $-\text{OCH}_2\text{Ph}$ ).  $^{13}\text{C}$  NMR:  $\delta$  26.0, 29.5, 31.2, 100.4, 138.2, 138.8.

**3-Methyl-3-butenyl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3o).** Yield: 92%, liquid.  $[\alpha]_D^{25} = +36.5$  ( $c$  1.4,  $\text{CH}_2\text{Cl}_2$ ). IR ( $\text{CH}_2\text{Cl}_2$ )  $\nu_{\text{max}}$ : 1603, 1163, 1095  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  1.71 (s, 3H,  $-\text{C}(\text{CH}_3)=\text{CH}_2$ ), 1.95-2.0 (dd,  $J = 12.8, 4.4$  Hz, 1H, H-2), 2.18-2.32 (m, H-2' and  $-\text{OCH}_2-\text{CH}_2-$ ), 3.45-3.64 (m, 4H, H-5, H-6, H-6' and  $-\text{OCH}-\text{CH}_2-$ ), 3.69-3.75 (m, 1H,  $-\text{OCH}'-\text{CH}_2-$ ), 3.88-3.94 (m, 2H, H-3, H-4), 4.40-4.52 (q,  $J = 11.7$  Hz, 2H,  $-\text{OCH}_2\text{Ph}$ ), 4.60 (br. s, 2H,  $-\text{OCH}_2\text{Ph}$ ), 4.62 (d,  $J = 11.7$  Hz, 1H,  $-\text{OCH}_2\text{Ph}$ ), 4.93 (d,  $J = 11.7$  Hz, 1H,  $-\text{OCH}_2\text{Ph}$ ), 4.72 (d,  $J = 11.0$  Hz, 2H,  $-\text{C}=\text{CH}_2$ ), 4.97 (br. d,  $J = 2.9$  Hz, 1H, H-1), 7.23-7.34 (m, 15H, aromatic).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  22.8, 31.2, 37.6, 65.8, 69.5, 69.8, 70.3, 72.9, 73.4, 74.2, 74.7, 97.6, 111.48, 127.2-138.8 (m, aromatic), 142.8. Characteristic signals for *b*-anomer:  $\delta$  22.7, 32.7, 37.5, 67.5, 69.2, 70.1, 71.6, 73.5, 74.0, 74.1, 100.3, 111.42, 142.6.  $\text{MSES}^+$ : 520  $[\text{M} + \text{NH}_4]^+$ . Anal. Calcd for  $\text{C}_{32}\text{H}_{38}\text{O}_5$  (502.64): C, 76.46; H, 7.62. Found: C, 76.49; H, 7.66.

**Octyl 3,4,6-tri-*O*-benzyl-2-deoxy- $\alpha/\beta$ -D-lyxo-hexopyranoside (3m).** Yield: 88%, liquid.  $[\alpha]_D^{25} = +27.5$  (*c* 1.7, CH<sub>2</sub>Cl<sub>2</sub>). IR (CH<sub>2</sub>Cl<sub>2</sub>)  $\nu_{\max}$ : 1163, 1095 cm<sup>-1</sup>; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  0.83-1.2 (m, 13H, *octyl*), 1.5-1.54 (m, 2H, -OCH<sub>2</sub>CH<sub>2</sub>-), 1.96-2.00 (dd, *J* = 12.4, 3.6 Hz, 1H, H-2), 2.18-2.25 (dt, *J* = 13.0, 3.6 Hz, 1H, H-2'), 3.32-3.38 (m, 1H, -OCH-CH<sub>2</sub>-), 3.54-3.66 (m, 3H, H-6, H-6' and -OCH-CH<sub>2</sub>-), 3.89-3.95 (m, 3H, H-3, H-4, H-5), 4.40-4.52 (q, *J* = 11.9 Hz, 2H, -OCH<sub>2</sub>Ph), 4.60 (br. s, 2H, -OCH<sub>2</sub>Ph), 4.62 (d, *J* = 11.5 Hz, 1H, -OCH<sub>2</sub>Ph), 4.93 (d, *J* = 11.5 Hz, 1H, -OCH<sub>2</sub>Ph), 4.96 (br. d, *J* = 3.1 Hz, 1H, H-1), 7.23-7.34 (m, 15H, aromatic). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):  $\delta$  22.6, 26.2, 29.2, 29.3, 29.5, 29.6, 31.2, 31.8, 60.4, 69.5, 69.7, 70.4, 73.0, 73.4, 74.2, 74.9, 97.6, 127-128 (m, aromatic), 138.3, 138.5, 138.9. MSES<sup>+</sup>: 546 [M + NH<sub>4</sub>]<sup>+</sup>. Anal. Calcd. for C<sub>36</sub>H<sub>50</sub>O<sub>5</sub> (562.78): C, 76.83; H, 8.96. Found: C, 76.88; H, 8.99.

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## References and Notes

1. Reddy, B. G.; Madhusudanan, K. P.; Vankar, Y. D. *J. Org. Chem.* **2004**, *70*, 2630.
2. Johnson, D. A.; Liu, H-W. *Comprehensive Natural Products Chemistry*, Barton, D.; Nakanishi,.; Meth-Cohn, O., Eds.; Elsevier: Oxford, 1999; Ch. 12, Vol.3.
3. (a) Remers, W. A. In *The Chemistry of Antitumor Antibiotics*; Wiley-Interscience: New York, 1979; pp 133-175. (b). Remers, W. A.; Iyengar, B. S. In *Cancer Chemotherapeutic Agents*; Foye, W. O. Ed; American Chemical Society, 1995; p 578.
4. Drautz, H.; Zahner, H.; Rohr, J.; Zeeck, A. *J. Antibiotics* **1986**, *39*, 1657.
5. (a) Lee, M. D.; Punne, T. S.; Chang, C. C.; Borders, D. B. *J. Am. Chem. Soc.* **1992**, *114*, 985. (b) Nicolaou, K. C.; Dai, W. M. *Angew. Chem., Int. Ed.* **1991**, *30*, 1387.
6. (a) Junnemann, J.; Lundt, I.; Thiem, J. *Liebigs Ann. Chem.* **1991**, 759. (b) Nicolaou, K. C.; Dolle, R. E.; Papahatjis, D. P. *J. Am. Chem. Soc.* **1984**, *106*, 4189. (c) Nicolaou, K. C.; Seitz, S. P.; Papahatjis, D. P. *J. Am. Chem. Soc.* **1983**, *105*, 2430. (d) Konradsson, P.; Mootoo, D. R.; Mc Devitt, R. E.; Fraser-Reid, B. *Chem. Commun.* **1990**, 270. (e) Castro-Palomino, J. C.; Schmidt, R. R. *Synlett* **1998**, 501. (f) Toshima, K.; Tatsuta, K. *Chem. Rev.* **1993**, *93*, 1503. (g) Hashimoto, S-I.; Sano, A.; Sakamoto, H.; Nakajima, Y.; Yanagiya, Y.; Ikegami, S. *Synlett* **1995**, 1271. (h) Li, H.; Zhao, K. *Tetrahedron Lett.* **1997**, *38*, 6143. (i) Truelove, J. E.; Hussain, A. A.; Kostenbauder, H. B. *J. Pharm. Sci.* **1980**, *69*, 231.
7. (a) Konradsson, P.; Mootoo, D. R.; Mc Devitt, R. E.; Fraser-Reid, B. *J. Am. Chem. Soc.* **1988**, *110*, 5583. (b) Frisen, R. W.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1989**, *111*, 6656.

- (c). Roush, W. R.; Narayan, S. *Org. Lett.* **1999**, *1*, 899. (d). Roush, W. R.; Narayan, S.; Bennett, C. E.; Briner, K. *Org. Lett.* **1999**, *1*, 895.
8. (a) Hadfield, A. F.; Sartorelli, A. C. *Carbohydr. Res.* **1982**, *101*, 197. (b) Sabesan, S.; Neira, S. *J. Org. Chem.* **1991**, *56*, 5468. (c) Bolitt, V.; Mioskowski, C.; Lee, S-G.; Falck, J. R. *J. Org. Chem.* **1990**, *55*, 5812.
9. (a) Toshima, K.; Nagai, H.; Ushiki, Y.; Matsumura, S. *Synlett* **1998**, 1007. (b) Yadav, J. S.; Reddy, B. V. S.; Reddy, B. K.; Satyanarayana, M. *Tetrahedron Lett.* **2002**, *43*, 7009.
10. Jaunzems, J.; Hofer, E.; Jesberger, M.; Sourkouni-Argirusi, G.; Kirschning, A. *Angew. Chem., Int. Ed.* **2003**, *42*, 1166.
11. Pachamuthu, K.; Vankar, Y. D. *J. Org. Chem.* **2001**, *66*, 7511.
12. (a) Rani, S.; Agarwal, A.; Vankar, Y. D. *Tetrahedron Lett.* **2003**, *44*, 5001. (b) Reddy, B. G.; Vankar, Y. D. *Tetrahedron Lett.* **2003**, *44*, 4765. (c) Rani, S.; Vankar, Y. D. *Tetrahedron Lett.* **2003**, *44*, 907. (d) Pachamuthu, K.; Das, J.; Gupta, A.; Schmidt, R. R.; Vankar, Y. D. *Eur. J. Org. Chem.* **2002**, 1479. (e) Gupta, A.; Vankar, Y. D. *Tetrahedron* **2000**, *56*, 8525.
13. Kimura, M.; Kajita, K.; Onoda, N.; Morosawa, S. *J. Org. Chem.* **1990**, *55*, 4887.
14. (a) Reddy, M. V. R.; Kumareswaran, R.; Vankar, Y. D. *Tetrahedron Lett.* **1995**, *36*, 7149. (b) Shahi, S. P.; Gupta, A.; Pitre, S. V.; Reddy, M. V. R.; Kumareswaran, R.; Vankar, Y. D. *J. Org. Chem.* **1999**, *64*, 4509.
15. The pH of the reaction mixture was found to be 2.5.
16. Lemieux, R. U.; Ratcliffe, R. M. *Can. J. Chem.* **1979**, *57*, 1244.